Shockwave Consolidation of Materials

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Agency:
Department of Defense

Release Date:
November 20, 2013
Branch:
Air Force

Open Date:
November 20, 2013
Program / Phase / Year:
SBIR / Phase I / 2014

Application Due Date:
January 22, 2014

Solicitation:
2014.1

Close Date:
January 22, 2014
Topic Number:
AF141-006

Description:
OBJECTIVE: To develop materials that are far from thermodynamic equilibrium domain (highly doped polycrystalline materials, nano-structured systems and supersaturated structures, etc.). The processing includes shockwave consolidation and external fields. DESCRIPTION: Conventional processing techniques typically prepare materials from a melt or using powder metallurgy techniques, such as hot pressing followed by sintering. These conventional techniques enable production of materials close to the equilibrium state with relatively large grains (crystallites) within the material and cause the loss of nanostructure dimensionality. Materials design and processing approaches at or close to the equilibrium state can impose limitations on the properties. Processing utilizing shockwave consolidation via explosions, high pressure gun systems, and/or electromagnetic waves (e.g., microwaves, electron beams, laser, etc.) may lead to new materials with desirable, tailorable properties. A specific thrust area of interest is the discovery of new techniques for consolidation of nano powders, measuring, and analyzing thermal phenomena induced by shock waves and under aforementioned external fields during processing. This requires understanding of the time domain and associated definition for the state of the material in relation to equilibrium state. The ultimate goal of exploiting these phenomena is to stabilize non-equilibrium phases and design future materials and components that break the paradigm of today"s materials where the boundaries of performance/failure are defined by the equilibrium state. The end-use areas could include, but are not limited to, transparent laser materials, multifunctional ceramics, shape memory alloys and reactive materials. PHASE I: 1. Define and design shockwave-driven processing techniques. 2. Demonstrate hierarchical stability of the microstructure as function of external stimuli, e.g., explosive compaction, high speed gas guns, or electromagnetic waves. 3. Design proof-of-

concept material in non-equilibrium state by demonstrating supersaturated dopant concentration (at least 10x of equilibrium dopant concentration). PHASE II: 1. Further improvements to material system and its properties. 2. Establish quantitative"Selection Rules"for stability of heterogeneous structures. Map out the non-equilibrium"phase diagram"enabled through shockwave processing. 3. Understand processing trade space by correlating time and length scales with emerging microstructure. 4. Identify and develop a cost-effective manufacturing technique to achieve non-equilibrium materials developed in Phases I and II. PHASE III DUAL USE APPLICATIONS: Continue development of the various aspects of shockwave consolidated materials to enable accomplishment of the Phase II objectives and deliverables. Transition the component technology to a DoD system integrator, mature it for operational insertion, and validation.